Check List the journal of biodiversity data

NOTES ON GEOGRAPHIC DISTRIBUTION

Check List 18 (2): 253–260
https://doi.org/10.15560/18.2.253

PENSOFT

First and recurrent records of *Stiphodon surrufus* Watson & Kottelat, 1995 (Gobiiformes, Gobiidae, Sicydiinae), a naturally rare amphidromous goby, in Sulawesi, Indonesia

Samliok Ndobe[1], Abdul Gani[2*], Achmad A. Bakri[3], Devita Tetra Adriany[3], Erwin Wuniarto[2], Lady Diana Khartiono[2], Muh Herjayanto[4], Veryl Hasan[5], Abigail M. Moore[6]

1 Faculty of Animal Husbandry and Fisheries, Tadulako University, Palu, Sulawesi Tengah, Indonesia • samndobe@yahoo.com https://orcid.org/0000-0003-4221-5205

2 Faculty of Fisheries, Muhammadiyah Luwuk University, Luwuk, Sulawesi Tengah, Indonesia • AG: abdulgani273085@gmail.com https://orcid.org/0000-0001-9730-4251 • EW: erwinwun28@gmail.com https://orcid.org/0000-0002-7469-1137 • LDK: ladykhartiono23@gmail.com https://orcid.org/0000-0003-2733-6156

3 Luwuk Banggai Fish Quarantine, Quality Control and Fisheries Product Safety Station, Luwuk, Sulawesi Tengah, Indonesia • AAB: 4chmad4fif@gmail.com https://orcid.org/0000-0002-3021-0370 • DTA: devita_adriany@yahoo.com https://orcid.org/0000-0001-8809-6286

4 Department of Fisheries, Sultan Ageng Tirtayasa University, Serang, Banten, Indonesia • herjayanto@untirta.ac.id https://orcid.org/0000-0002-6121-3523

5 Department of Aquaculture, Faculty of Fisheries and Marine, Universitas Airlangga, Surabaya, Jawa Timur, Indonesia • veryl.hasan@fpk.unair.ac.id https://orcid.org/0000-0001-5457-9335

6 Graduate School, Universitas Hasanuddin, Makassar, Sulawesi Selatan, Indonesia • abigail@pasca.unhas.ac.id https://orcid.org/0000-0002-4122-3740

* Corresponding author

Abstract

Stiphodon surrufus Watson & Kottelat, 1995, with its recent synonym *S. birdsong* Watson, 1996, is recorded from widely separated locations in the Western Pacific, including Papua and Halmahera in eastern Indonesia. We collected a single specimen of male *S. surrufus* from the Bohi River, Banggai District, Central Sulawesi Province, Indonesia in 2019; this represents the first record of *S. surrufus* from Sulawesi, the largest island in the Wallacea biodiversity hotspot. Three additional specimens were collected in 2020, one in 2021, and two in 2022, all from the same site. These records expand the known distribution of a naturally rare but widespread sicydiine goby and contribute to the underexplored but increasingly threatened Sulawesian riverine ichthyofauna.

Keywords

Bohi River, Gobiidae, Luwuk Banggai, range extension, Sicydiinae, Wallacea

Academic editor: Valter Azevedo-Santos | Received 27 June 2021 | Accepted 25 February 2022 | Published 4 March 2022

Citation: Ndobe S, Gani A, Bakri AA, Adriany DT, Wuniarto E, Khartiono LD, Herjayanto M, Hasan V, Moore AM (2022) First and recurrent records of *Stiphodon surrufus* Watson & Kottelat, 1995 (Gobiiformes, Gobiidae, Sicydiinae), a naturally rare amphidromous goby, in Sulawesi, Indonesia. Check List 18 (2): 253–260. https://doi.org/10.15560/18.2.253

©The authors. This is an open access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Introduction

Sicydiine gobies of the genus *Stiphodon* M.C.W. Weber, 1895 are distributed in subtropical and tropical freshwater streams from Sri Lanka to French Polynesia, and from the Ryukyu Islands, Japan to north-eastern Australia, including the Indonesian Archipelago (Keith et al. 2011). Many sicydiine gobies have an amphidromous life cycle (McDowall 1999; Ebner et al. 2011; Keith and Lord 2012). The adults of several genera, including *Stiphodon*, are generally confined to clear, often fast-flowing streams (Ebner et al. 2011; Keith and Hadiaty 2014; Keith et al. 2015a). Amphidromous gobioid post-larvae recruiting to freshwater typically form multi-species shoals which can include *Stiphodon* species (Nurjirana et al. 2019; Sahami and Habibie 2020). These post-larval shoals are heavily fished for human consumption in some areas (Keith and Lord 2012), including Sulawesi (Ambo-Rappe and Moore 2019; Sahami and Habibie 2020). Furthermore, a growing number of sicydiine gobies, including the genus *Stiphodon*, are increasingly sought for an expanding niche market in the freshwater aquarium trade (Ebner et al. 2011; Maeda and Tan 2013; Seriously Fish 2021). Like the post-larval fisheries, the emerging fisheries for ornamental amphidromous gobies in Sulawesi are at present unregulated and mostly unreported. Responsible fisheries management relies on knowledge of, in particular, species' distributions (Caddy 1996).

Riverine gobies in the Indo-Pacific, including Indonesia, are understudied, as reflected by recent surveys of Indonesian riverine ichthyofauna which have resulted in the description of new species (Keith and Hadiaty 2014; Keith et al. 2015b, 2020), as well as range extensions for previously described species (Keith et al. 2015c; Gani et al. 2021a). Conversely, some nominal species are now regarded as synonyms; for example *Stiphodon birdsong* Watson, 1996 is now considered a junior synonym of *Stiphodon surrufus* Watson & Kottelat, 1995 based on morphological (Keith et al. 2015a) and genetic (Lor 2016) characters. Incorporating reports for *S. surrufus* and *S. birdsong*, this taxon is known from regions with a latitudinal range from Yukushima Island (Ryuku Islands), southern Japan (Yonezawa et al. 2010) to north-eastern Australia (Ebner et al. 2011) and a longitudinal range from Leyte Island, Philippines (Watson and Kottelat 1995) to the Solomon Islands (Boseto et al. 2007). The known range of *S. surrufus* also includes Palau (Lor 2016), Halmahera, Papua and Biak in eastern Indonesia, and Papua New Guinea (Watson 1996; Watson et al. 1998).

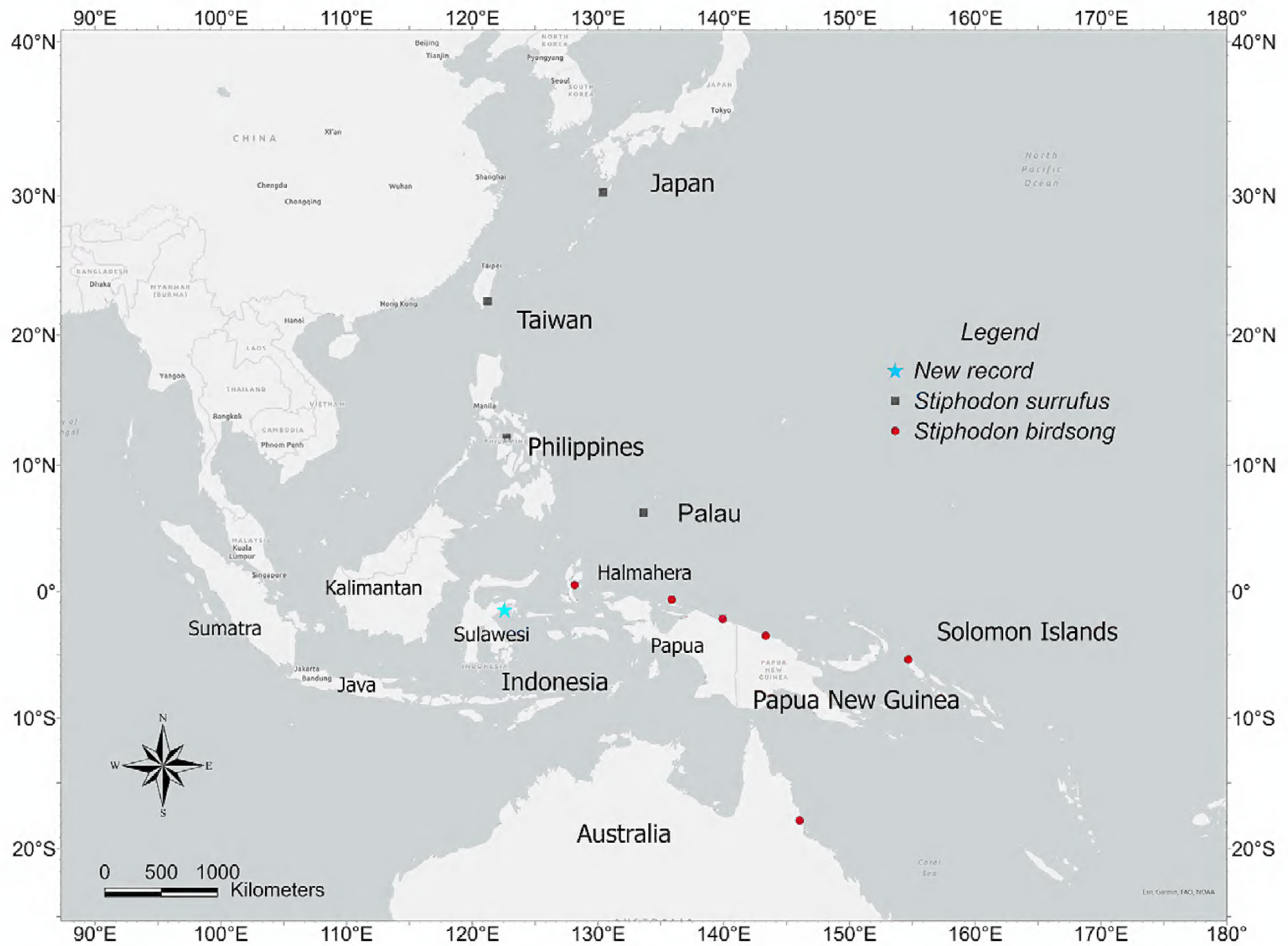

Figure 1. Recorded distribution of *Stiphodon surrufus* in the Western Pacific region. The blue star denotes the recent record from Central Sulawesi, Indonesia; black squares indicate previous records originally reported as *S. surrufus* and red circles indicate records originally recorded as *S. birdsong*. Data sources: Boseto (2012); Ebner et al. (2011); Keith et al. (2015); Lor (2016); Sakaue (2007) in Jaafar (2018); Watson and Kottelat (1995); Watson (1996); Watson et al. (1998); Yonezawa et al. (2010); Zhou and Gao (2011) in Jaafar (2018).

During an expedition to explore the gobioid ichthyofauna of the Luwuk Banggai region in Central Sulawesi Province on the eastern side of Sulawesi Island, Indonesia, on 15 November 2019 we collected a specimen of *S. surrufus* from the Bohi River. This specimen represents the first record of *S. surrufus* from Sulawesi, the largest island in Wallacea, and a westward extension of the known geographic range of this species (Fig. 1). Six additional specimens were subsequently collected from the same site.

Methods

Specimens of *S. surrufus* were caught with a scoop net in the upper reaches of the Bohi River, about 6 km from the sea (Gulf of Tolo) in Luwuk Subdistrict, Banggai District, Central Sulawesi Province, Indonesia (Fig. 2). Here, the Bohi River is a swiftly flowing stream with crystal clear waters running over a mixed rocky and sandy substrate through dense rainforest (Fig. 3). All specimens were euthanized with MS222, preserved in 96% ethanol (Hasan and Tamam 2019), and deposited at the Dry Laboratory, Fish Quarantine, Quality Control and Fisheries Product Safety Station, Luwuk Banggai, Indonesia (FCLB).

Diagnostic morphological and meristic characters of the specimens were examined following Watson and Kottelat (1995) and Keith et al. (2015a); however, scales were counted only for the first specimen (FCLB 068/SKILB/SP.I/IV/2019). Morphological examination was complemented with photographs of the live colouration taken immediately after capture. Measurements and counts were obtained from the left side of the first specimen collected from the Bohi River. Measurements were taken from point to point using digital callipers with a precision of 0.1 mm and reported as a percentage of the standard length (SL) giving the range with the mean value in brackets. Fin rays/spines and scales were counted under a stereomicroscope (Leica MZ6). Counts were reported as a range, with mean values in brackets.

Results

Stiphodon surrufus Watson & Kottelat, 1995

Figure 4; Table 1

New records. INDONESIA – Central Sulawesi • Banggai District, Luwuk, upper reaches of the Bohi River; 01°01′39″S, 122°42′40″E; 15.XI.2019; A. Gani, A.A. Bakri and D.T. Adriany leg.; 1 ♂, 41.0 mm SL, FCLB 068/SKILB/SP.I/IV/2019 • same locality as the preceding; 07.III.2021; A. Gani, Afif leg.; 3 ♂, 40–42 mm SL, FCLB 152a/SKILB/SP.I/VI/2020, 152bSKILB/SP.I/VI/2020, 152cSKILB/SP.I/VI/2020 • same locality as the preceding; 13.II.2021; A. Gani, Afif leg.; 1 ♂, 26 mm SL, FCLB 143/SKILB/SP.I/III/2021 • same locality as the preceding; 26.I.2022; A. Gani, Afif leg.; 2 ♂, 30–37 mm SL, FCLB 167/SKILB/SP.I/I/2022, 168/SKILB/SP.I/I/2022.

Identification. Diagnostic characters for *S. surrufus* within the genus *Stiphodon* observed in our specimens include: a naked predorsal midline; absence of gill rakers on the inner edge of the gill arch; absence of filamentous rays on the first dorsal fin; first dorsal fin same height as second dorsal fin, dorsal fin spine not elongate or filamentous; posterior margin of caudal fin rounded; strong cup-like pelvic disc formed by joined pelvic fin rays, adherent to belly at base between fifth rays; anal fin directly below second dorsal fin. Colouration in fresh specimens: lateral sides of head, body, and tail vivid orange; belly whitish; dorsal region brownish; dark scale margins in caudal region; first and second dorsal fins pale reddish brown with 3–5 black spots along each ray. Caudal fin orange proximally with hyaline margins and 3–5 black spots along several rays. Pectoral fin without remarkable markings. Anal fin reddish brown with a dusky submarginal band (Fig. 3). Meristic characters of the male *S. surrufus* and from the original descriptions of *S. surrufus* (Watson and Kottelat 1995) and *S. birdsong* (Watson 1996), as well as from several subsequent records (Keith et al. 2015a), are given in Table 1.

Discussion

Central Sulawesi is the third region in Indonesia from which the presence of *S. surrufus* has been reported; the two previous regions were Papua and Halmahera (Watson 1996; Watson et al. 1998). Our new records of *S. surrufus* extend the known geographic range of *S. surrufus* in the equatorial region westwards to Sulawesi, a major island with many clear streams providing extensive potential habitat with conditions similar to sites where *S. surrufus* has been reported in other areas (Ebner and Thuesen 2010; Donaldson et al. 2013; Ebner et al. 2021). The Bohi River site in Sulawesi is around 700 km (in a straight line) south-west from the Halmahera site, while the sites in the Philippines, Papua, and Palau are approximately 1,200 km, 1,500 km, and 1,600 km, respectively, from our newly recorded site in Sulawesi. The western shore of Halmahera faces Sulawesi across the Molucca Sea; however, the collection site of the *S. birdsong* specimen from Halmahera in Watson (1996) was the Ifis River, in Wasile Utara Subdistrict, Halmahera Timur District, at the tip of the north-east branch of Halmahera. This river flows into the Halmahera Sea on the eastern side of Halmahera, facing Papua. In terms of seaways and potential connectivity, data from Ocean Surface Current Analysis Real-time (OSCAR; accessible through the NASA on-line portal https://podaac.jpl.nasa.gov) show highly variable and complex currents in the seas east of Sulawesi. These data suggest that larval dispersal to the eastern coast of Sulawesi from any of the known sites would likely be a rare event, whether from Palau or the three nearer sites (Halmahera, Philippines, and Papua). Unusual patterns of connectivity have been reported in this region for other taxa (Umar et al. 2019). A multi-taxon concordant phylogeographic break

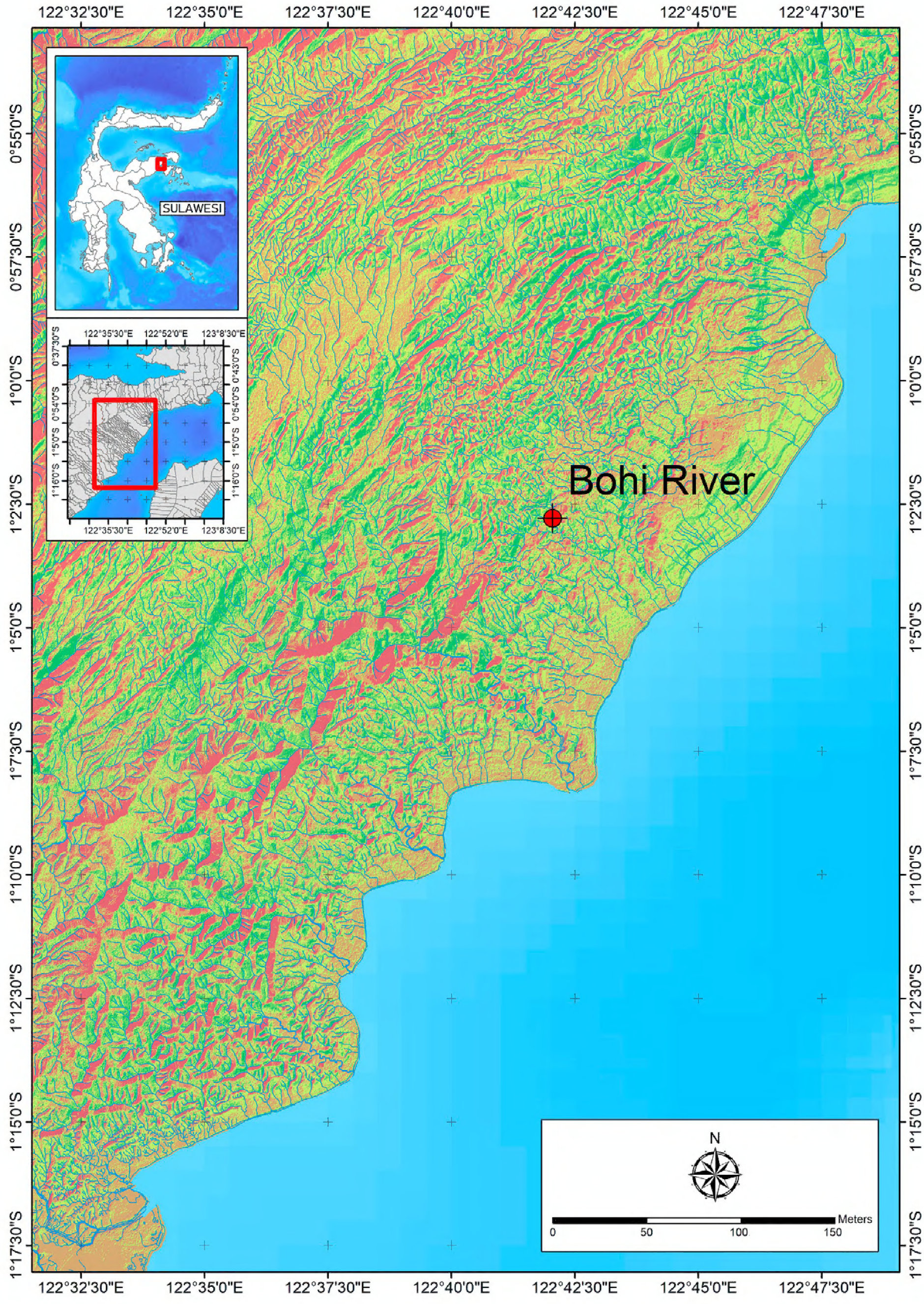

Figure 2. The *Stiphodon surrufus* collection site on the Bohi River in Banggai District, Central Sulawesi Province, Indonesia.

Figure 3. Bohi River, collection site of *Stiphodon surrufus* in Central Sulawesi, Indonesia.

between Halmahera and Sulawesi has been proposed (Carpenter et al. 2011), and potential barriers to dispersal have been identified between Sulawesi and the locations of all other *S. surrufus* records (Treml et al. 2015). However, amphidromous gobies present in one or more of these regions have been reported in the Luwuk Banggai region and/or other regions of Sulawesi (Gani et al. 2021a; Keith and Mennesson 2020). Further exploration to discover as yet unrecorded populations and studies using molecular (DNA) markers could help to clarify the phylogeography of this rare and patchily distributed but widespread species.

Some sicydiine goby species are considered highly vulnerable to extirpation or even extinction (Keith 2003; Walter et al. 2012; Ebner et al. 2016). Their amphidromous nature can render them vulnerable to environmental changes (Yamasaki and Tachihara 2006; Keith et al. 2009), especially during the riverine, estuarine, and marine larval and post-larval stages (Keith and Lord 2012; Teichert et al. 2021). IUCN Red List assessments are available for 30 *Stiphodon* species: seven species (23.3%) are classified in one of the at-risk categories, 12 (40%) are Least Concern, and 11 (37%) are Data Deficient. Population trends are unknown for 22 species (73.3%), including *S. surrufus* (IUCN 2021). *Stiphodon surrufus* was originally classified as Vulnerable under the IUCN Red List criteria, with threats identified including the likelihood of anthropogenic disturbance to critical habitats (Kottelat 1996). The recently synonymised *S. birdsong* (Keith et al. 2015a) was assessed as Least Concern in 2011 (Boseto 2012) due to its widespread distribution and lack of known major threats, with the caveat that the species appears to be naturally rare over most of its distribution (Papua, Indonesia; Papua New Guinea; Solomon Islands) and extremely rare in Australia (Queensland). A revised assessment of *S. surrufus* in 2020 reclassified the species as Least Concern, based on the consideration that the wide geographic spread of *S. surrufus* populations means that stochastic events may lead to local extirpations but unlikely to cause global extinction (Jaafar 2019). However, the paucity of data on the biology, ecology, and population trends was noted, with a recommendation for further research on this species.

Our collection of this species in four consecutive years strongly suggests an established population rather

Figure 4. Specimen of male *Stiphodon surrufus* (FCLB 168/SKILB/SP.I/I/2022) from the Bohi River, Central Sulawesi, Indonesia.

Table 1. Meristic characters of male *Stiphodon surrufus* from the Bohi River, Central Sulawesi, Indonesia (present study); Leyte, Philippines (Watson and Kottelat 1995); Halmahera and New Guinea (Watson 1996); and several sites (Keith et al. 2015a).

Character	Present study	Watson and Kottelat 1995	Watson 1996[a]	Keith et al. 2015[b]
First dorsal fin rays	VI	VI	VI	VI
Second dorsal fin rays	I+9	I+9	I+9	I+9
Anal fin rays	I+10	I+10	I+10	I+10
Caudal fin rays	13	11–13	12–13	11–13
Pectoral fin rays	14	14	14	13–15
Scales in lateral series	33	19–36	16–21	12–36
Scales in transverse backward series	14	10–14	2–12	2–15

[a] As *Stiphodon birdsong*.

[b] Includes data for the synonymised *S. birdsong*.

than stochastic recruitment of an isolated individual, as might have been inferred from the finding of a single specimen in 2019. The rarity of the species in other regions and the low number of specimens collected at the Bohi River site (one in 2019, three in 2020, one in 2021, and two in 2022) indicate that this goby is likely naturally present in low abundances. However, due to the amphidromous lifestyle of *Stiphodon*, it seems unlikely that *S. surrufus* would be restricted to just one stream along the eastern coast of Sulawesi. Tropical streams are diverse, ecologically important but often understudied environments, where anthropogenic impacts can cause rapid changes, often before baseline data have been collected (Smith et al. 2003). Although most rivers in eastern Indonesia, including Papua, Halmahera, and Sulawesi, are generally considered to be relatively free from industrial pollution compared to western Indonesia, mining and land conversion are increasing threats to many regions of Sulawesi, including Banggai District (Lasut et al. 2010; Muhammad et al. 2012; Ambo-Rappe and Moore 2019; Rijal et al. 2019; Kadir et al. 2020). No *S. surrufus* were found during ichthyological expeditions to 11 nearby rivers (Gani et al. 2019, 2020, 2021a, 2021b); however, sampling efforts to date represent limited stretches of a tiny proportion of the rivers and streams potentially providing suitable habitat in Central Sulawesi Province. Further data collection efforts are needed to assess the abundance and distribution of *S. surrufus* in the Bohi River and similar riverine habitat nearby, along the east coast of Sulawesi, and in other areas of Sulawesi, and to determine the threats facing each watershed.

No human uses are listed in the FishBase records for *S. surrufus* and *S. birdsong* (Froese and Pauly 2021). Similarly, the IUCN Red List assessment for *S. surrufus* makes no mention of any form of exploitation. The detailed threats section states that this species does not appear to have any direct threats "although impacts to its habitat, such as runoff, pollutants, barriers to migration, and development of riparian areas, affect populations" (Jaafar 2019: 5). However, collection of fishes from rivers in the Luwuk Banggai area for the freshwater ornamental fish trade appears to have begun around April 2021. Since then, the frequency and volume of mixed species consignments airfreighted from Luwuk to ornamental fish traders in Jakarta have increased. Regulation of this ornamental fishery and trade is at present limited to the statutory pre-flight procedures required by the Fish Quarantine, Quality Control and Fisheries Product Safety Station. While the manifests do not provide species-level data, we have seen consignments containing *S. surrufus* and other amphidromous gobies. This recent development highlights the urgency of exploring and managing Sulawesian freshwater biodiversity and, in particular, establishing the taxonomy and systematics of the species present. This is vital for understanding the ecology and biology of Sulawesian fishes, including determining species' distributions at a fine (e.g., watershed) scale and habitat needs throughout their respective life cycles as well as the composition and functioning of aquatic communities. Such knowledge and understanding are needed to evaluate the potential for sustainable ornamental fisheries and to inform conservation and fisheries management measures. In the current situation where data on target species are still extremely limited, a precautionary approach is highly recommended. At a minimum, this should include improved resolution of the data collected on freshwater/amphidromous taxa dispatched from regions such as Luwuk Banggai, and this could be achieved through regulations at subnational (district/city, provincial) and/or national levels, enabling *inter alia* the leveraging of existing fish health and quarantine procedures.

Understanding the distribution of sicydiine gobies is important in the context of amphidromous species diversity and biogeography (Ebner et al. 2011; Maeda and Palla 2015; Hasan et al. 2021). Our new distributional data on *S. surrufus* reinforces indications of historical and/or contemporary connectivity of amphidromous species between Sulawesi, in particular the Gulf of Tolo coast of eastern Sulawesi, and other islands in Wallacea and eastern Indonesia more generally, including the Sahul Shelf ecoregion. Irrespective of the extent of *S. surrufus* distribution around Sulawesi, our findings also reinforce the importance of Sulawesian inland waters, especially riverine habitat, as breeding areas and migration routes for amphidromous gobies.

Acknowledgements

We thank the Rector of Muhammadiyah Luwuk University, the Luwuk Banggai Fish Quarantine, Quality Control and Fisheries Product Safety Station, Expedisi Riset Akuatika (ERA), and all who provided supported for this research including the local field team and guides. We thank Halwi and Novarman for assistance with the maps (Figs. 1, 2), as well as Intje Hajri and Rahmat A. S. Tuntu for assistance in the field and in photographing *S. surrufus* (Fig. 4). We are grateful to the reviewers and editor for their insightful comments.

Authors' Contributions

Conceptualization: SN, AG. Data curation: SN, AMM. Investigation: AG, AAB, DTA, EW, LDK. Methodology: SN, MH, VH. Resources: AG, AAB, DTA, EW. Writing – original draft: SN, AG, AMM. Writing – review and editing: SN, AG, AAB, DTA, EW, LDK, MH, VH, AMM.

References

Ambo-Rappe R, Moore AM (2019) Sulawesi Seas, Indonesia. In: Sheppard C (Ed.), World seas: an environmental evaluation, volume II: the Indian Ocean to the Pacific. Elsevier Academic Press, London, UK, 559–581. https://doi.org/10.1016/B978-0-08-100853-9.00032-4

Boseto D (2012) *Stiphodon birdsong*. The IUCN Red List of threat-

ened species 2012: e.T196394A2452850. https://doi.org/10.2305/iucn.uk.2012.rlts.t196394a2452850.en

Boseto D, Morrison C, Pikacha P, Pitakia T (2007) Biodiversity and conservation of freshwater fishes in selected rivers on Choiseul Island, Solomon Islands. The South Pacific Journal of Natural and Applied Sciences 25: 16–21. https://doi.org/10.1071/sp07003

Caddy JF (1996) A checklist for fisheries resource management issues seen from the perspective of the FAO Code of Conduct for Responsible Fisheries. FAO Fisheries Circular: Vol. 917 FIRM/C. Food and Agriculture Organization of the United Nations, Rome, Italy, 21 pp. http://www.fao.org/docrep/w3140e/w3140e00.htm. Accessed on: 2022-2-26.

Carpenter KE, Barber PH, Crandall ED, Ablan-Lagman MCA, Ambariyanto Mahardika GN, Manjaji-Matsumoto BM, Juinio-Meñez MA, Santos MD, Starger CJ, Toha AHA (2011) Comparative phylogeography of the coral triangle and implications for marine management. Journal of Marine Biology 2011: 396982. https://doi.org/10.1155/2011/396982

Donaldson JA, Ebner BC, Fulton CJ (2013) Flow velocity underpins microhabitat selection by gobies of the Australian wet tropics. Freshwater Biology 58: 1038–1051. https://doi.org/10.1111/fwb.12107

Ebner BC, Thuesen P (2010) Discovery of stream-cling-goby assemblages (*Stiphodon* species) in the Australian wet tropics. Australian Journal of Zoology 58: 331–340. https://doi.org/10.1071/zo10061

Ebner BC, Donaldson JA, Sydes TA (2016) Conservation planning for cling gobies and short-steep-coastal-streams in the Australian wet tropics. Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER), James Cook University, Cairns, Australia, 76 pp.

Ebner BC, Thuesen PA, Larson HK, Keith P (2011) A review of distribution, field observations and precautionary conservation requirements for sicydiine gobies in Australia. Cybium 35: 397–414. https://doi.org/10.26028/cybium/2011-354-013

Ebner BC, Donaldson JA, Murphy H, Thuesen P, Ford A, Schaffer J, Keith P (2021) Waterfalls mediate the longitudinal distribution of diadromous predatory fishes structuring communities in tropical, short, steep coastal streams. Freshwater Biology 66 (6): 1225–1241. https://doi.org/10.1111/fwb.13712

Froese R, Pauly D (Eds.) (2021) FishBase. https://www.fishbase.org. Accessed on: 2021-10-9.

Gani A, Bakri AA, Adriany DT, Nurjirana N, Herjayanto M, Bungalim MI, NdobeS, Burhanuddin AI (2019) Identification of freshwater goby species from the Biak and Koyoan Rivers, Luwuk Banggai, Central Sulawesi. Jurnal Ilmu Kelautan Spermonde 5 (2): 57. https://doi.org/10.20956/jiks.v5i2.8931

Gani A, Wuniarto E, Khartiono LD, Srinurmahningsi, Mutalib Y, Nurjirana, Herjayanto M, Satria DH, Adam MI, Jusmanto, Bungalim MI, Adriany DT, Bakri AA, Subarkah M, Burhanuddin AI (2020) A note on Gobiidae from some rivers in Luwuk Banggai, Central Sulawesi, Indonesia. IOP Conference Series: Earth and Environmental Science 473: 012054. https://doi.org/10.1088/1755-1315/473/1/012054

Gani A, Nurjirana, Bakri AA, Adriany DT, Wuniarto E, Khartiono LD, Satria DH, Hasan V, Herjayanto M, Burhanuddin AI, Moore AM, Kobayashi H (2021a) First record of *Stiphodon annieae* Keith & Hadiaty, 2015 (Teleostei, Oxudercidae) from Sulawesi Island, Indonesia. Check List 17 (1): 261–267. https://doi.org/10.15560/17.1.261

Gani A, Adam MI, Bakri AA, Adriany DT, Herjayanto M, Nurjirana, Mangitung SF, Andriyono, S (2021b) Diversity studies of freshwater goby species from three rivers ecosystem in Luwuk Banggai, Central Sulawesi, Indonesia. IOP Conference Series: Earth and Environmental Science 718 (1): 012087. https://doi.org/10.1088/1755-1315/718/1/012087

Hasan V, Tamam MB (2019) First record of the invasive Nile tilapia, *Oreochromis niloticus* (Linnaeus, 1758) (Perciformes, Cichlidae), on Bawean Island, Indonesia. Check List 15 (1): 225–227. https://doi.org/10.15560/15.1.225

Hasan V, Valen FS, Islamy RA, Widodo MS, Saptadjaja AM, Islam I (2021) Short Communication: presence of the vulnerable freshwater goby *Sicyopus auxilimentus* (Gobiidae, Sicydiinae) on Sangihe Island, Indonesia. Biodiversitas 22: 571–579. https://doi.org/10.13057/biodiv/d220208

IUCN (2021) The IUCN Red List of threatened species. Version 2021-2. https://www.iucnredlist.org. Accessed on: 2021-10-9.

Jaafar Z (2019) *Stiphodon surrufus*. The IUCN Red List of threatened species 2019: e.T20855A91083089. https://doi.org/10.2305/iucn.uk.2019-2.rlts.t20855a91083089.en

Kadir A, Suaib E, Zuada LH (2020) Mining in Southeast Sulawesi and Central Sulawesi: shadow economy and environmental damage regional autonomy era in Indonesia. Advances in Social Science, Education and Humanities Research 404: 20–27. https://doi.org/10.2991/assehr.k.200214.004

Keith P (2003) Biology and ecology of amphidromous Gobiidae of the Indo-Pacific and the Caribbean regions. Journal of Fish Biology 63: 831–847. https://doi.org/10.1046/j.1095-8649.2003.00197.x

Keith P, Lord C (2012) Tropical Freshwater Gobies: Amphidromy as a Life Cycle. In: Patzner RA, van Tassell, James L, Kovačić M, Kapoor BG (Eds.) The biology of gobies. CRC Press, Boca Raton, USA, 243–277. https://doi.org/10.1201/b11397-18

Keith P, Hadiaty RK (2014) *Stiphodon annieae*, a new species of freshwater goby from Indonesia (Gobiidae). Cybium 38: 267–272. https://doi.org/10.26028/cybium/2014-384-004

Keith P, Mennesson M (2020) Review of *Giuris* (Teleostei: Eleotridae) from Indo-Pacific islands, with description of three new species. Cybium: 44 (4): 331–349. https://doi.org/10.26028/cybium/2020-444-004

Keith P, Marquet G, Pouilly M (2009) *Stiphodon mele* n. sp., a new species of freshwater goby from Vanuatu and New Caledonia (Teleostei, Gobiidae, Sicydiinae), and comments about amphidromy and regional dispersion. Zoosystema 31: 471–483. https://doi.org/10.5252/z2009n3a5

Keith P, Lord C, Maeda K (2015a) Indo-Pacific sicydiine gobies: biodiversity, life traits and conservation. Société Française d'Ichtyologie, Paris, France, 256 pp.

Keith P, Busson F, Sauri S, Hubert N, Hadiaty RK (2015b) A new *Stiphodon* (Gobiidae) from Indonesia. Cybium 39: 219–225. https://doi.org/10.26028/cybium/2015-393-005

Keith P, Lord C, Busson F, Sauri S, Hubert N, Hadiaty R (2015c) A new species of *Sicyopterus* (Gobiidae) from Indonesia. Cybium 39: 243–248. https://doi.org/10.26028/cybium/2015-393-005

Keith P, Lord C, Lorion J, Watanabe S, Tsukamoto K, Couloux A, Dettai A (2011) Phylogeny and biogeography of Sicydiinae (Teleostei: Gobiidae) inferred from mitochondrial and nuclear genes. Marine Biology 158: 311–326. https://doi.org/10.1007/s00227-010-1560-z

Keith P, Mennesson MI, Sauir S, Busson F, Delrieu-Trottin E, Limmon G, Nurjirana, Dahruddin H, Hubert N (2020) *Giuris* (Teleostei: Eleotridae) from Indonesia, with description of a new species. Cybium 44: 317–329. https://doi.org/10.26028/cybium/2020-444-003

Kottelat M (1996) *Stiphodon surrufus*. The IUCN Red List of threatened species 1996: e.T20855A9231471. https://doi.org/10.2305/iucn.uk.1996.rlts.t20855a9231471.en

Lasut MT, Yasuda Y, Edinger EN, Pangemanan JM (2010) Distribution and accumulation of mercury derived from gold mining in marine environment and its impact on residents of Buyat bay, north Sulawesi, Indonesia. Water, Air, and Soil Pollution 208: 153–164. https://doi.org/10.1007/s11270-009-0155-0

Lor V (2016) Understanding species diversity of the amphidromous Indopacific goby genus *Stiphodon* (Gobiidae: sicydiinae). MSc thesis, Texas A&M University–Corpus Christi, Corpus Christi, USA, 56 pp.

Maeda K, Tan HH (2013) Review of *Stiphodon* (Gobiidae: Sicydiinae) from western Sumatra, with description of a new species. Raffles Bulletin of Zoology 61: 749–761.

Maeda K, Palla HP (2015) A new species of the genus *Stiphodon* from

Palawan, Philippines (Gobiidae: Sicydiinae). Zootaxa 4018: 381–395. https://doi.org/10.11646/zootaxa.4018.3.3

McDowall RM (1999) Different kinds of diadromy: different kinds of conservation problems. ICES Journal of Marine Science 56: 410–413. https://doi.org/10.1006/jmsc.1999.0450

Muhammad B, Uswah H, Isrun NUR, Yuka S (2012) Gold mining activities and its impacts on land degradation in central Sulawesi, Indonesia. Journal of Ecotechnology Research 16: 79–83. https://doi.org/10.11190/jer.16.79

Nurjirana, Burhanuddin AI, Haris A (2019) Diversity of *penja* fish (amphidromous goby) in Leppangan River, West Sulawesi, Indonesia. AACL Bioflux 12: 246–249.

Rijal S, Barkey RA, Nasri, Nursaputra M (2019) Profile, level of vulnerability and spatial pattern of deforestation in Sulawesi period of 1990 to 2018. Forests 10: 191. https://doi.org/10.3390/f10020191

Sahami F, Habibie S (2020) Exploration of adult phase of *Nike* fish to maintain its sustainability in Gorontalo Bay waters, Indonesia. AACL Bioflux 13: 2829–2867.

Sakaue J (2007) Field report from Palau. Aqua Life 398: 109–115.

Seriously Fish (2021) Seriously fish. Profile search *Stiphodon* https://www.seriouslyfish.com/species/search/Stiphodon. Accessed on: 2021-10-11.

Smith GC, Covich AR, Brasher AMD (2003) An ecological perspective on the biodiversity of tropical island streams. BioScience 53: 1048–1051. https://doi.org/10.1641/0006-3568(2003)053[1048:aeptob]2.0.co;2

Teichert N, Lagarde R, Occelli N, Ponton D, Gaudin P (2021) Water temperature influences larval survival of the amphidromous goby *Sicyopterus lagocephalus*. Ecology of Freshwater Fish 00: 1–10. https://doi.org/10.1111/eff.12602

Treml EA, Roberts J, HalpinPN, Possingham HP, Riginos C (2015) The emergent geography of biophysical dispersal barriers across the Indo-West Pacific. Diversity and Distributions 21 (4): 465–476. https://doi.org/10.1111/ddi.12307

Umar W, Tassakka ACMAR, Barbe, PH, Jompa J (2019) Unexpected patterns of genetic connectivity in *Lobophyllia corymbosa* (Forskål, 1775) around Sulawesi, Indonesia. Biodiversitas 20 (9): 2744–2749. https://doi.org/10.13057/biodiv/d200940

Walter RP, Hogan JD, Blum MJ, Gagne RB, Hain EF, Gilliam JF, Mcintyre PB (2012) Climate change and conservation of endemic amphidromous fishes in Hawaiian streams. Endangered Species Research 16: 261–272. https://doi.org/10.3354/esr00404

Watson RE (1996) A review of *Stiphodon* from New Guinea and adjacent regions, with descriptions of five new species (Teleostei: Gobiidae: Sicydiinae). Revue Française d'Aquariologie 23: 113–132.

Watson RE, Kottelat M (1995) Gobies of the genus *Stiphodon* from Leyte, Philippines, with descriptions of two new species (Teleostei: Gobiidae: Sicydiinae). Ichthyological Exploration of Freshwaters 6: 1–16.

Watson RE, Allen GR, Kottelat M (1998) A review of *Stiphodon* from Halmahera and Irian Jaya, Indonesia, with descriptions of two new species (Teleostei: Gobiidae). Ichthyological Exploration of Freshwaters 9: 293–304.

Yamasaki N, Tachihara K (2006) Reproductive biology and morphology of eggs and larvae of *Stiphodon percnopterygionus* (Gobiidae: Sicydiinae) collected from Okinawa Island. Ichthyological Research 53: 13–18. https://doi.org/10.1007/s10228-005-0307-1

Yonezawa T, Shinomiya A, Motomura H (2010) Freshwater fishes of Yaku-shima Island, Kagoshima Prefecture, southern Japan. In: Motomura H, Matsuura K (Eds.) Fishes of Yaku-shima Island. National Museum of Nature and Science, Tokyo, Japan, 249–261.

Zhou M. Gao R (2011) The freshwater and estuarine fishes of Taiwan. Morning Star Publishing, Taichung, Taiwan, 381 pp.